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Liquid-solid coexistence in mixed lipid membranes

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近年、多成分の脂質二重膜において,L_α(液体相) と $L_{\beta'}$(固体相) の共存が実験的に観察されている (1)。我々は文献 (2) の一成分系のモデルを拡張することによって、膜の曲率と分子の配向が結合したランダウ自由エネルギーを提案する。その際、分子の配向はベクトル場で記述し、L_α-$L_{\beta'}$ 転移が一次転移であることを考慮した。それによって、温度と弾性係数に対する相図を Fig.1 のように求めた。このモデルをさらに拡張することにより、二成分混合系における側方相分離についても考察した。

It is known that lipid bilayers form various lamellar phases such as L_α (liquid) phase in which the hydrocarbon chains are disordered, $L_{\beta'}$ (solid) phase in which they are ordered, or $P_{\beta'}$ phase (rippled phase) in which the membranes are spatially modulated. For binary lipid mixtures, phase separations between different phases occur. Recently, coexistence between L_α and $L_{\beta'}$ phases was experimentally observed (1).

We first discuss the model of the structural transition among various phases for single component lipid membranes. We extend the Landau free energy in Ref. (2) so that the L_α-$L_{\beta'}$ transition is first-order. Here the molecular orientation is described by a vector field, and a coupling between the membrane curvature and the molecular orientation is taken into account. The calculated phase diagram is given in Fig. 1. We further consider the lateral phase separation and the membrane structure for binary lipid membranes. We determine various coexistences between the liquid and the solid phases.

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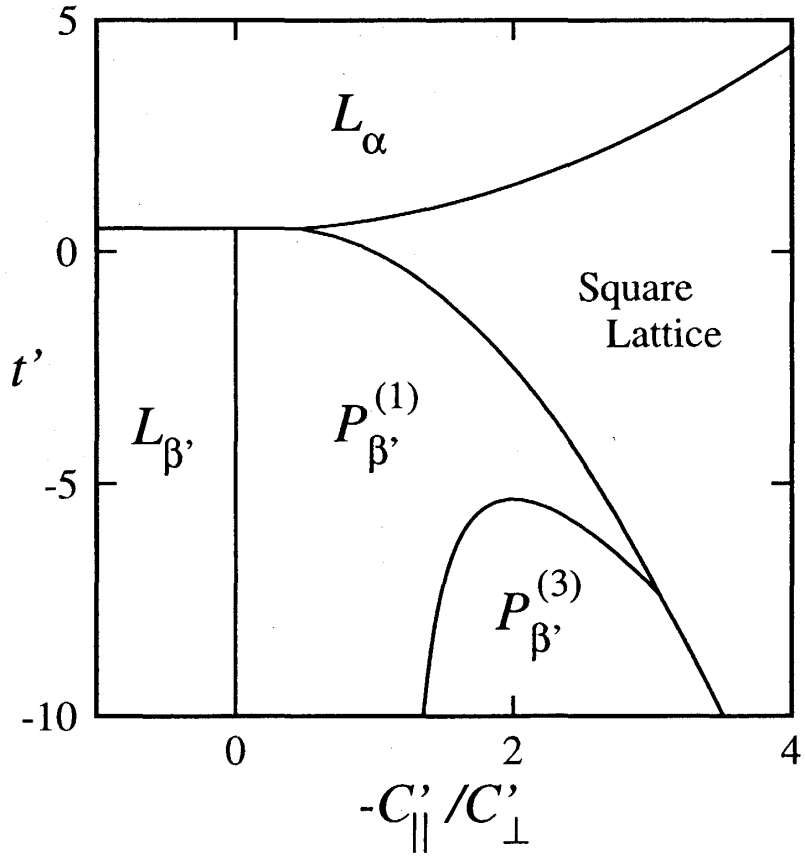

Figure 1: The calculated phase diagram of a single component lipid membrane as a function of the reduced temperature t' and the reduced elastic constant $-C'_{\parallel}/C'_{\perp}$. L_{α} is the disordered liquid phase, $L_{\beta'}$ is the ordered solid phase, $P^{(1)}_{\beta'}$ and $P^{(3)}_{\beta'}$ are the 1D modulated phases, and the square lattice phase is the 2D modulated phase.